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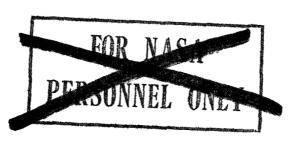
FLIGHT CREW TRAINING PROGRAM

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MANNED SPACECRAFT CENTER HOUSTON, TEXAS



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This paper is not subject for general distribution or referencies at may be referenced only in other working arrespondence and documents on Project Descripting by participating organizations.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

OCTOBER 12, 1962

NASA WORKING PAPER NO. 10,001

FLIGHT CREW TRAINING PROGRAM

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

, 1962 OCTOBER

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INTRODUCTION

The enclosed training program has been formulated to follow the Mercury training activities. It is tailored to provide a broad spectrum of engineering participation, basic science lectures, and operational training for the Mercury pilots and the new flight crew personnel.

This training program will have as its primary objective the preparation of flight crews for the long duration and rendezvous missions that are postulated for Gemini. In addition to their Gemini engineering development activities and operational training, the pilots will participate in the continuing operational aspects of Mercury and work in the conceptual and development phases of Apollo.

Basic science courses will be given early in the program concurrent with the initial project-oriented engineering activities. Later phases of the program will be focused on hardware development and operational training utilizing static and dynamic flight simulators.

TRAINING PROGRAM

Chart No. I on page 2 presents an over-all view of the training program through calendar year 1963. Detailed training schedules during 1963 will be determined by flight hardware and trainer availability.

A basic science program has been defined to give all pilots an updated technical background in the physics of space environment, the lunar environment, space mechanics, guidance and navigation, and fundamentals of spacecraft and launch vehicle technology.

Mercury, Gemini and Apollo Project familiarizations are scheduled concurrent with the basic science program to prepare the pilots for project-oriented design and operational activities. Detailed Gemini systems training is scheduled in the second quarter of 1963 to give the pilots a thorough knowledge of the flight hardware systems.

Chart No. II on page 6 is a detailed schedule of the project familiarization, basic science program, environmental familiarization and survival training.

As in Mercury, the men will be assigned pilot coordination and design responsibilities associated with the spacecraft and boosters. They will also be assigned operational planning duties.

CHART I

Operational training utilizing flight simulators is scheduled later in 1963 to:

- (1) familiarize the astronauts with space flight conditions,
- (2) prepare them to a high level of proficiency in systems management, flight procedures, and control tasks,
- (3) give them intimate knowledge of emergency procedures, and
- (4) integrate flight crews and ground operational support teams.

A series of weekly seminars will be scheduled which will keep the pilots up to date on the X-15 and Dyna-Soar programs, space science programs such as Ranger and Surveyor, meteorological and communications satellites, the results of radiation probes and ground radiation experiments, large liquid and solid rocket development, ion and nuclear rocket technology, space station plans, and the Russian space program.

Project Familiarization. This portion of training consists of briefings and discussions on the Mercury, Gemini and Apollo spacecraft and launch vehicles. These briefings are outlined in Appendix A and scheduled in Chart No. II. The Mercury briefings will be given by MSC personnel during the first week of training. In the second week, the pilots will visit Cape Canaveral for general orientation on facilities and specific familiarization with Project Mercury operations and Gemini and Apollo launch facilities.

The initial Gemini and Apollo spacecraft familiarization briefings, as well as the detailed systems study utilizing the systems trainers, will be given by Flight Crew Operations Division personnel. Visits to the spacecraft contractors facilities will be scheduled from time to time during the development program.

In order to include an inspection of hardware, the launch vehicle briefings will be carried out at the manufacturers plants.

Basic Science Program. The basic science courses are outlined in Appendix B. The duration of each course as shown on Chart No. II was defined by allotting a two or four-hour period per course per week. In order to accomplish these courses in an efficient manner, Monday and Tuesday of each week have been set aside specifically for this work and all other training activities scheduled around them. The courses that will be provided are:

- 1. Astronomy
- 2. Rocket Propulsion Systems
- 3. Flight Mechanics
- 4. Computers
- 5. Guidance and Navigation
- 6. Aerodynamics
- 7. Communications
- 8. Environmental Control Systems
- 9. Physics of the Upper Atmosphere and Space
- 10. Medical Aspects of Spaceflight
- 11. Selenology
- 12. Global Meteorology

A typical week's schedule of training activities is presented on page 5.

General Environmental Familiarization and Survival Training. Familiarization with various portions of the space environment and survival training are discussed in the following paragraphs and are scheduled as shown in Chart No. II.

A. Accelerations: A Gemini centrifuge program at the Naval Air Development Center, Johnsville, Pennsylvania, of approximately four weeks duration will be accomplished in the first quarter of 1963. One purpose of the program is to familiarize the new flight crews with the Gemini launch and reentry "g" profiles. A second objective of the program is to evaluate Gemini crew station equipment such as the hand controller, seat and restraint system, and dynamic displays. The acceleration profiles will be patterned after the normal Gemini boost, reentry, and abort trajectories. The reentry phase will be programmed closed loop on the computer. Each pilot will receive two or three two-hour periods on the centrifuge.

Typical Week's Schedule

| Saturday | Flying | |
|-----------|---|------------------|
| Friday | Gemini Spacecraft Systems and Operations Briefings 8 to 12 A. M. 1 to 4 P. M. | Physical Fitness |
| Thursday | Gemini Spacecraft Systems and Operations Briefings 8 to 12 A. M. 1 to 4 P. M. | Physical Fitness |
| Wednesday | Gemini Spacecraft Systems and Operations Briefings 8 to 12 A. M. | Physical Fitness |
| Tuesday | Guidance and Navigation Basic Science Course 8:00 to 10:00 A. M. 10:30 to 12:30 A. M. Computers Basic Science Course 1:30 to 3:30 P. M. | Physical Fitness |
| Monday | Rocket Propulsion Systems Basic Science Course 8:30 to 10:30 A. M. Flight Mechanics Basic Science Course 10:30 to 12:30 A. M. Astronomy Basic Science Course 2:30 to 4:30 P. M. | Physical Fitness |

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| Discheduled Water | Mercury | | | | | | | | | | |
| Dracteduled Transit | Cape Canaveral Tour | | | | | | | | | | |
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| Discheduled Water | | | | | | | | | | | |
| Discheduled Water | Navigation | | | | | | | | | | I |
| Discheduled Water | | | | | | | | | | | |
| Discheduled Water | | | | | | | | | | | |
| Discheduled Water | | | | | | | | | | | |
| Dischediiled Water | Physics of the Upper Atmosphere | | | | | | | | | | |
| Unschedilled Water | | | | | | | | - | | | |
| Unscheduled | | | | | | | | | | | |
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| ilon Thomas | ENVIRONMENTAL FAMILIARIZATION; SURVIVAL | | | | | | | | | | |
| tion Transfer Transfer Transfer Water | Acceleration | | | | | | | | | | |
| tion Transfer Transfer Transfer Water | Weightlessness | | | | | | | | | | |
| Thomas Travelo | COo Indoctrination | | | Unscheduled | | | | | | | |
| Thomas . Trapic Water | Pressure Suit Indoctrination | | | | | | - | | | | \Box |
| monais Water | Parachute Jump Training | | | | | | | | | | |
| | Survival: Water, Desert, Tropic | | | | | Tropic | | Water | Desert | | |

Page 7

- B. Weightlessness: The pilots will fly zero "g" familiarization in the Wright Air Development Division modified C-135.
- C. Vibration and Noise: No special training will be provided in this area. However, exposure to vibrational modes and noise environment of the launch vehicle is included in the part-task launch abort training to be received on the Ling-Temco-Vought simulator. The launch noise environment will also be simulated in the Gemini mission simulators.
- D. CO₂ Indoctrination: The flight crews will be trained to recognize their individual symptoms due to high concentrations of CO₂. This training will be conducted by the Life Systems Division of the Manned Spacecraft Center.
- E. Pressure Suit Indoctrination: The crews will be familiarized with the operation of the pressure suit, its capabilities in heat protection, and its mobility pressurized and unpressurized. The training will be conducted by Life Systems Division personnel of the Manned Spacecraft Center.
- F. Survival: Water A two to three-day program on water survival techniques will be taught, utilizing both classroom discussions and practical experience. This course will be conducted by MSC personnel.
 - Tropic A one-week program on tropic survival will be accomplished with the support of the Department of Defense.
 - Desert Another week will be allotted to a comprehensive program on desert survival, including field experience under actual desert conditions.
- G. Parachute Training: Since both Gemini and Apollo plan to use individual personal parachutes, a short course in parachute jumping is planned.

Spacecraft and Launch Vehicle Design and Development. The pilots will participate in and contribute to spacecraft and launch vehicle design and development, by means of the activities listed below:

- A. Attend spacecraft and launch vehicle engineering and mock-up reviews.
- B. Participate in specific contractor and MSC design and development studies.

- C. Attend the various internal and contractor meetings which are of concern to the pilots.
- D. Participate in pressure suit and personal equipment development.
- E. Follow Project ground test programs.

Operational Training (Gemini). The operational training is described in the following paragraphs by defining the training to be accomplished on each simulator. Chart No. III on page 9 shows the predicted date that each simulator or trainer will be available for training purposes, and the scheduled time of training.

A. Mock-Up Trainer

Familiarize the pilots with the crew station layout at an early stage in the spacecraft development period.

B. Flight Trainers (Mission Simulators)

- 1. Familiarize the flight crew with the over-all mission timing and with the specific tasks called out in the mission flight plan.
- 2. Acquaint crew with dynamic characteristics of capsule as simulated by the flight instruments and visual displays in response to automatic and manual control inputs.
- 3. Train the flight crew in the procedural aspects of spacecraft systems failure detection and correction.

C. Egress Trainer

Provide training in methods and procedures for normal and emergency egress.

D. Centrifuge Training

To familiarize the flight crew with finalized launch and reentry operational procedures under realistic acceleration levels.

E. In-flight Paraglider Trainer

Train the flight crew by actual experience in flying the spacecraft in the final approach and touchdown control phase of the mission.

JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC CHART III - GEMINI OPERATIONAL TRAINING \forall Modification Couttinuous Informat Training Formel Training Period Redefipt of Trainer . 18 NOV DEC. 18 NOV DEC. 18 NOV DEC. 18 NOV DEC. 19 NOV DEC. 18 NOV DEC. 19 N Translation and Docking Trainer Vought Launch Abort Simulation Centrifuge Training Equipment In-Flight Paraglider Trainer Mission Simulator II Mission Simulator I Egress Trainer Mock Up

Page 9

F. Translation and Docking Trainer

Train flight crews in a dynamic trainer in the control of the Gemini spacecraft during the docking maneuver.

In conjunction with the training on the MSC simulators and trainers, industry facilities and other NASA organizations will be used in the best interests of the training program. The facilities include the Ling-Temco-Vought simulator for launch abort simulation, the Martin Apollo simulator for total mission simulation, the North American Aviation lunar landing simulator, and the NASA Langley Research Center's docking simulator and lunar landing simulator.

Aircraft Flight Program. Aircraft flying proficiency will be maintained through the use of T-33 and F-102 aircraft assigned to the MSC and based at Ellington Air Force Base.

The flight crews will also receive several helicopter flights in order to acquaint them with the problems and techniques of visual orientation and control during the vertical descent landings.

Physical Fitness Program. The flight crews will maintain a high standard of physical fitness by working out on a personal basis. Facilities will be provided for this activity at Ellington Air Force Base.

APPENDIX A

OUTLINES OF SPACECRAFT AND LAUNCH VEHICLE BRIEFINGS

MERCURY FAMILIARIZATION BRIEFINGS

- I. Flight Program and Over-all Mission
- II. Tracking and Communications Network
- III. Launch Vehicle
- IV. Spacecraft Systems
 - A. Introduction to the Mercury Spacecraft
 - B. Automatic Stabilization and Control System
 - C. Reaction Control, Manual Control, Rate Stabilization Control System
 - D. Environmental Control System
 - E. Communications and Instrumentation System
 - F. Miscellaneous Mercury Systems
- V. Operations
 - A. Launch
 - B. Flight Control
 - C. Medical Monitoring
 - D. Recovery
- VI. Prelaunch Training
- VII. Astronaut's Flight Tasks
- VIII. Manned One-Day Mission Concepts

CAPE CANAVERAL TOUR AND BRIEFINGS

- I. Spacecraft Checkout (Hangar)
- II. Pad Checkout (Spacecraft and Launch Vehicle)
- III. Countdown Operation
 - IV. Mercury Control Center Operations
 - V. Launch Vehicle Guidance and Control
 - VI. Central Control Operations
- VII. Side Trip to Visit Pratt and Whitney RL 10 Engine Facility at West Palm Beach, Florida

GEMINI LAUNCH VEHICLE DESIGN AND OPERATION

(MATIT)

- I. Performance (trajectory, sequence and dynamics)
- II. Systems operation
- III. Systems monitoring during launch
- IV. Abort criteria and manual abort

A field trip of two days duration to the Martin Company and one day to Aerojet General will be accomplished to receive the above briefings and to view the construction and checkout of the Titan Launch Vehicle.

AGENA, GEMINI RENDEZVOUS CONFIGURATION

- I. Performance
- II. Systems operation
- III. Post-docking control
 - IV. Docking Equipment

A field trip of one day duration to Lockheed Sunnyvale will be scheduled to receive the above briefings and view the construction of the hardware.

GEMINI SYSTEMS AND OPERATION

BRIEFING

- I. Gemini Mission and General Abort
 - A. Spacecraft and Launch Vehicle Gemini Titan Agena

- B. Mission Profile
 Operational modes
 General crew tasks
 Rendezvous considerations
- C. Abort Modes

II. Mechanical Systems

- A. Propulsion OAMS RCS Retro
- B. Environment Control
 Pressurization, gas purification
 Thermal Control-spacecraft

III. <u>Electrical Systems</u>

- A. Guidance and Control
 Equipment
 Operating modes
- B. Power
 Sources Fuel Cell and Batteries
 Distribution
- C. Communications
 Equipment
 Operating modes

IV. Interior Arrangement and Crew Activities

- A. Cockpit Equipment
 - 1. Displays and controls
 - 2. Escape System
 - 3. Life Support Equipment
- B. Mission Management
 - 1. Boost and Abort
 - 2. Orbit
 - 3. Rendezvous and Docking
 - 4. Gemini/Agena Mission
 - 5. Reentry and Landing

APOLIO LAUNCH VEHICLES DESIGN AND OPERATION

(C-1, C-1B, C-5)

- I. Propulsion systems
- II. Systems operation
- III. Systems monitoring during powered phases of flight
- IV. Malfunction detection system

The above briefings will be conducted at Marshall Space Flight Center and Douglas Aircraft Corporation (S IV Stage).

APOLLO SYSTEMS AND OPERATION BRIEFING

I. Mission Description

- A. Mission objectives and schedule
- B. Vehicle description
 C-1, C-1B
 C-5
 Command module
 Service module
 Lunar excursion module
- C. Mission Phases

Launch

Translunar injection

Midcourse

Lunar orbit

De-orbit

Lunar landing

Lunar take-off

Rendezvous

Transearth

Entry

Landing

D. Abort Considerations

II. Spacecraft Systems

- A. Environmental Control
 Oxygen system
 Thermal control
 - B. Propulsion
 CM Attitude control
 SM Attitude control
 SM propulsion
 Launch escape
 - C. Electrical Electronic
 Guidance and navigation
 Stabilization and control
 Power Generation and distribution
 In-Flight Test System
 - D. Recovery system
 Chutes
 Landing attenuation

III. Interior Arrangement

- A. General Arrangement
- B. Displays and Controls
- C. Abort System
- D. Life Support Equipment

IV. Crew Activities

- A. Launch
- B. Translunar injection
- C. Midcourse
- D. Lunar orbit
- E. De-Orbit and Lunar Landing
- F. Lunar Take-Off and Rendezvous
- G. Transearth
- H. Entry and Landing

APPENDIX B

OUTLINES OF THE BASIC SCIENCE COURSES

ASTRONOMY

I. SPACE

- A. Fundamental concepts and definitions
- B. Coordinate systems
- C. The Earth as a Celestial Body and its Motions

II. TIME

- A. Fundamental definitions
- B. Light
- C. Celestial Navigation
- D. Telescopes and their equipment and accessories

III. THE MOON

- A. Its motions
- B. Its surface features, and Moon Maps
- C. Tides
- D. Lunar and Solar Eclipses -- Their Importance

IV. THE SOLAR SYSTEM

- A. The Physics of the solar system -- Basis of Celestial Mechanics
- B. Survey of the planets and their satellites
- C. Comets, meteors, meteorites

V. THE SUN

- A. Its radiation and temperature
- B. The photosphere (solar surface) and its physics
- C. The physics of sunspots, and their importance
- D. Flares, Prominences, and other activity, and their importance
- E. Associated Ionospheric disturbances

VI. THE STARS

- A. Distances
- B. Motions
- C. Stellar classification and stellar spectra
- D. Magnitudes and luminosites
- E. Variable stars
- F. Binary stars

VII. STELLAR ATMOSPHERES AND INTERIORS -- The physics of:

- A. Atomic structure and radiation
- B. Stellar atmospheres
- C. Extended atmospheres and envelopes
- D. Stellar interiors

VIII. STELLAR AGGREGATES

- A. Star Clusters
- B. Interstellar dust and gas
- C. The Galaxy
- D. The Exterior Galaxies

ROCKET PROPULSION SYSTEMS

I. Physics of Rocket Propulsion

- A. Rocket Vehicle Performance
 - 1. Equations defining stage performance
 - 2. Theoretical optimization of stages
 - 3. Practical techniques using digital computers
 - 4. Trajectory losses
 - a. drag losses
 - b. gravity losses
 - c. potential energy velocity losses
- B. Rocket Engine Performance
 - 1. Equations defining nozzle exit velocity (specific impulse)
 - a. frozen equilibrium
 - b. shifting equilibrium
 - c. parameters dependent upon propellant physics
 - d. nozzle expansion ratio
 - 2. Equations relating to mass flow, throat area, chamber pressure, et cetera
- C. Solid Propellant Grain Design
 - 1. Grain geometry, burning rate and relation to throat to port area, chamber pressure, and thrust.
 - 2. Film animating calculation procedure and phenomenon represented by each step of the calculation.
- D. Performance and Physical Properties of Some Liquid
 - 1. Propellants used and proposed for our Gemini, Apollo and follow-on programs.

II. Practical Rocket Engine Design

- A. Thrust Chamber Design Considerations
 - 1. Combustion instability modes and solutions
 - 2. Injector design considerations and typical examples
 - a. fixed thrust injectors
 - b. variable thrust injectors
 - c. influence on chamber and nozzle design
- B. Ablative Material Chambers
 - 1. Materials
 - 2. Fabrication techniques
 - 3. Chamber and nozzle form
 - 4. Ablation design considerations
 - a. ablation rates nominal
 - b. effects film cooling
 - c. emergency
- C. Regenerative Cooled Chambers
 - 1. Materials
 - Fabrication techniques examples of present state-of-art
 - 3. Heat transfer considerations
- D. Turbopump Liquid Engine Cycles
 - 1. Gas generator cycles
 - a. H-1 engine schematic
 - b. J-2 engine schematic
 - c. M-l engine schematic
 - 2. Regenerative cycles
 - a. RL10 cycle

III. Propulsion System Design

- A. Pressurization System Description
 - 1. Invert gas systems
 - a. cold
 - b. heated
 - 2. Vaporized propellants
 - a. Titan system
 - b. H, engine bleed systems
 - c. Ho systems for pressure-fed systems
 - 1. heated H_2 auxiliary tank
 - 2. pumped heated H
 - d. Solid grain gas generators

- B. Tankage and Main Feed System Design Considerations
 - l. Tank design
 - 2. Propellant utilization
 - 3. Propellant valve arrangement
- C. Complete System Schematic examples
 - 1. SM systems
 - 2. LEM systems

FLIGHT MECHANICS

I. Basic Principles of Rocket Flight

- A. Conventional Motors versus Rocket Motors
- B. Significant Parameters in determining Rocket Performance
- C. Influence of thrust, mass flow rate and aerodynamic configuration of rockets and guided missiles upon their launch trajectories
- D. Mathematical discussion of rockets and guided missiles in flight including a detailed presentation of typical powered flight trajectories

II. Orbital Mechanics

- A. The application of Kepler's Laws to orbital flight of earth satellites
- B. The precision determination of orbital flights of manned space vehicles around the earth
- C. Orbital transfer maneuvers
- D. The determination of lunar trajectories
- E. The mechanics of lunar trajectories

III. Re-entry Mechanics

- A. Ballistic type re-entry trajectories
- B. Lifting type re-entry trajectories
- C. Heat shield design trajectories (including the interrelations among weights, re-entry ranges and re-entry guidance)

IV. Rendezvous Mechanics

- A. Launch Windows for rendezvous missions
- B. Plane change considerations in rendezvous missions
- C. In-plane catchup considerations leading to rendezvous
- D. The terminal phase in rendezvous mission
- E. The space station and lunar orbital rendezvous missions
- F. Ground monitoring of the rendezvous phase

COMPUTERS

I. Number Systems

- A. Decimal
 - 1. Form
 - 2. Levels
 - 3. Representation
- B. Binary
 - 1. Form
 - 2. Levels
 - 3. Representation
 - 4. Conversion
 - 5. Arithmetic

II. Computer Logic

- A. Boolean Algebra
 - 1. Theorems
 - 2. Mathematical Relationships
- B. Building Blocks
 - 1. And
 - 2. Or
 - 3. Not
- C. Half Adder
- D. Full Adder

III. Computer Form

- Α. Input
 - 1. Cards
 - 2. Paper tape
 - 3. Magnetic tape
 - 4. Direct
- B. Output
 - 1. Cards
 - 2. Paper tape
 - Magnetic tapeDirect

 - 5. Printed page

- C. Arithmetic
 - 1. Parallel
 - 2. Serial
 - 3. Multiply-divide macros
- D. Memory
 - 1. Core

 - Disk
 Magnetic tape
 - 4. Thin film
- E. Logic
 - 1. Level of sophistication
 - 2. Asynchronous Operation
- F. Buffering
- G. Trapping

IV. Stored Program

- A. Instructions
 - 1. Arithmetic
 - 2. Logical
 - 3. Input/Output
- B. Constants
 - 1. Fixed Point
 - 2. Floating Point
- C. Data
- D. Instruction Arithmetic
 - 1. Direct Modification
 - 2. Index Registers

Problem Solving ٧.

- A. Statement of problem
 - 1. Input Format
 - 2. Work to be accomplished
 - 3. Output Format
- B. Numerical Analysis
- C. Flow Chart
- D. Code
- E. Debug
- F. Run

VI. Programming Methods

- A. Machine language
- B. Assembly programs
- C. Compilers

VII. Fortran

- A. Arithmetic Expressions
- B. Conditional Statements
- C. Declarations
- D. Input/Output Statements
- E. Typical Problem

GUIDANCE AND NAVIGATION

- I. Introduction and problem survey. Navigation review. General principles of design and operation of guidance, stabilization, and control equipment. Open-chain and closed-chain control systems. Analogue and digital computation compared. Relevant mathematics. How differential equations are used. Space and time variables. Coordinate systems. Transformations. Vectors.
- II. <u>Trajectories and Mid-course Guidance</u>. Extra-terrestrial trajectory determination. Orbital injection. Interplanetary celestial navigation. Ballistic guidance. Guidance for satellite rendezvous. Atmospheric reentry guidance. Specification of position in space.
- III. Powered Flight Guidance. Sources of the equations to be mechanized. Boundary conditions. Limits of validity. Guidance equations. Method of mechanization.
- IV. Gyros. Radiative energy density transport rate as a vector to be measured. Acceleration as a vector to be measured. Requirement for reference coordinate axes. Instrumented reference axes. Gyros as axis-keepers. The single-axis stabilized platform. Base motion and base-to-platform coupling. Angular acceleration. Friction. Viscous coupling. Internal working of single-degree-of-freedom gyros. Demonstration. Integrating gyros. Rate gyro. System roles. Inertial measuring unit. Stabilization and control system. Gyros' role in autopilot.
- V. Stabilization. Optical and gyro stabilization compared. Limits of accuracy in stabilization. Stabilization and navigation problem. Inertial axes and rotating axes.

Page 25

- VI. Accelerometers. Basic principle. Force rendered as displacement; elasticity. Measurement from stationary and rotating bases compared. "Fictitious" forces. Integrating accelerometers. Quantization and integration. The digital accelerometer.
- VII. <u>Computers</u>. Computational character of all instrumentation, as distinct from its performance character. Customary restrictions on term "computer". Analogue and digital computation. Accuracy, flexibility, compactness, reliability. Arithmetic and incremental digital computers compared. Applications to trajectory study; system design; guidance and control of spacecraft. Specific mathematical operations. Differentation. Integration. Timing pulses; time bases; real time and computer time.
- VIII. Optics. Basic principles. Theories of light. Reflection and refraction. Mirrors and lenses. Paraxial rays. Thin lenses. Approximations in design. Stars and planets as objects for optical systems. Dynamics of atmospheric refraction. Use of the standard sextant and the Apollo sextant compared. Details of Apollo sextant. Interaction of sextant and inertial measuring unit. Sextant-established star lines compared with inertial-measuring unit inertial axes, as navigational position references. Corrective-thrust role in midcourse.
- IX. Autopilots. Review of the aircraft autopilot problem. Slow and fast vehicles. Comparison with space autopilot. Thrust control methods. Role of gyros. Body-mounted gyros compared with stabilized instruments. The computational function of the autopilot loop; commands. Digital character. The monitoring function of the autopilot loop. Performance for these two functions. Corrective-thrust role in midcourse.
- X. Electromagnetic Radiation Instrumentation. Review of basic radar principles. Introduction to the laser and other types of radiative devices. Roles of electromagnetic radiative instrumentation during lunar landing and lunar rendezvous.
- XI. Reentry guidance. A typical reentry program in detail. Boundaries on deceleration. Instrumentation used in reentry. Importance of attitude. Reliance on gyros. Role of accelerometers in reentry.
- XII. Review and Examination. The review of principles is made by considering in time-sequence the operation of the guidance and control equipment on a mission. The principles and functions are stressed, rather than procedures.

AERODYNAMICS

I. Newtonian Flow Theory

- A. Equations
- B. Bodies (general)
- C. Mercury and Apollo

II. Reentry Configurations

- A. Cone
- B. Eggers-Wong 1/2 cone
- C. Apollo

III. Reentry Performance

- A. Entry corridor
- B. Footprint
- C. Lift modulation

IV. Reentry Heating

- A. Environment
- B. Materials
- V. Abort Considerations (atmospheric)
- VI. Iaunch Vehicle Aerodynamics
- VII. General Performance Requirements for Advanced Manned Missions
- VIII: General Configuration Requirements for Advanced Manned Missions

IX. Aerodynamic test programs

- A. Wind tunnel
- B. Free-flight
- C. Others

COMMUNICATIONS

I. Subject Matter

- A. R. F. Systems
- B. Antennas
- C. Television
- D. Radar
- E. Telemetry
- F. Physiological Electronics
- G. Optical Communications

II. Each subject will be covered in relation to the following outline

- A. Title
- B. Introduction
 - 1. History
 - 2. General requirements of manned missions
 - 3. Importance of system
- C. Background Theory
 - 1. As required, according to audience background
- D. System Analysis
 - 1. Overall
 - a. General development, indicating subsystems
 - b. Restrictions on system, tolerances
 - c. Capabilities of the system
 - 2. Detailed
 - a. By subsystems
 - b. Indication of critical subsystems
 - c. In-flight replacement and/or repair
 - 3. Discussion of state-of-the-art
 - a. Influence on design
 - b. Possible improvements
 - 4. Problem Areas
 - a. Effects on mission
 - 5. Operational requirements on astronauts
 - a. Special skills required
 - b. Additional training

ENVIRONMENTAL CONTROL SYSTEMS

I. Definition

II. Physiological Requirements

- A. Oxygen pressure
- Total pressure В.
- C. Temperature
- D. Humidity
- E. Carbon Dioxide
- F. Contaminants
- G. Ventilation
- H. Perspiration rate
- I. Water requirements

III. Subsystem Description

- Temperature Control
 - 1. Water boilers
 - 2. Radiators
 - 3. Cryogenics (cryocycle)
 - 4. Vapor cycle
- Humidity Control
 - 1. Condensation
 - 2. Absorption
 - 3. Adsorption
 - 4. Electrodialysis
- C. Water Separation
 - 1. Sponge
 - 2. Wick
 - 3. Centrifugal
 - Inertia
- Carbon Dioxide Control
 - Chemical Non-regenerative-LiOH, LiO2
 - Regenerative-Molecular sieve, silver oxide
 - 3. Electrodialysis4. Leakage
 - Leakage

- E. Atmosphere Supply
 - 1. Gaseous Oxygen
 - 2. Supercritical Oxygen
 - 3. Liquid Oxygen
 - 4. Recovery from Carbon Dioxide or Water Vapor
- F. Contamination Control
 - 1. Activated Charcoal
 - 2. Catalytic Burners
 - 3. Leakage
- G. Ventilation
 - 1. Blowers
 - 2. Ejectors
- H. Water Management
 - 1. Water Recovery from perspiration
 - 2. Water Recovery from Urine
- I. Waste Management

IV. Classic Examples of Integrated Systems

- A. Mercury
- B. Gemini
- C. Apollo
- D. Advanced Systems

PHYSICS OF THE UPPER ATMOSPHERE AND SPACE

- I. Atmosphere
 - A. Environment
 - B. Origin of Ionized Layers
 - C. Visual Effects
 - 1. Auroral Displays
 - 2. Ionospheric shells
 - 3. Trails of Meteors
 - 4. Air Glows

II. Space

- A. Environment
- B. Meteors and Dust
- C. Particle Distribution-Van Allen Belts (Theory of Origin)
- D. Visual Effects
 - 1. Zodiacal Light
 - 2. Gegenschein
 - 3. Suns Flares
- E. Temperature Considerations

MEDICAL ASPECTS OF SPACEFLIGHT

| _ | Introduction | |
|------|-------------------|---|
| I. | I DEPOSITE OF | 1 |
| -L a | TILOT OURGE OF OF | |

Normal Human Environmental Envelope

- II. Respiration
- III. Cardiovascular Function
- IV. Eyes and Ears

Vibration and Sound

- V. Gastrointestinal and Genitourinary
- VI. Nervous System
- VII. Acceleration
 - A. Weightlessness
 B. "G" forces
- VIII. Compression and Decompression
 - IX. Spatial Disorientation
 - X. Radiation
 - XI. Physiological monitoring
 - XII. First Aid as Applied Physiology
- XIII. Pharmacology

SELENOLOGY

- I. Introduction
 - A. History of Lunar Observations
 - B. Basis of Today's State of Knowledge
- II. Origin of the Moon
 - A. Theories of Origin
 - B. Relationship of Exploration to Our Knowledge of Moon's Origin
- III. Lunar Atmosphere
- IV. Lunar Interior
- V. Lunar Surface
 - A. Geophysical Factors
 - B. Geochemical Factors
 - C. Geological Factors
- VI. Exploration of Lunar Surface

GLOBAL METEOROLOGY

- I. Motions of Air Masses (Large Scale)
- II. Cloud Formations
- III. Meteorological Cycle (Effect of Extraneous Disturbances i.e., Sunspots, et cetera)
 - IV. Visual Observation of Weather Systems